

## DESCRIPTION

IN-MOLD COATING METHOD AND IN-MOLD-COATED MOLDED PRODUCT

## 5 Technical Field

The present invention relates to in-mold coating methods in which resin is molded and is coated with a coating material (which may also be referred to as paint) by injecting and curing the coating material between the 10 resin molded product and the mold cavity surface, and also to in-mold-coated molded products formed by the methods. In particular, the present invention relates to an in-mold coating method suitable for providing a uniform coating thickness to produce a molded product with an excellent 15 external appearance, and also to an in-mold-coated molded product formed by the in-mold coating method.

## Background Art

Conventionally, painting is often employed as a method 20 for decorating molded products molded with thermoplastic resins.

According to a typical painting method, a molded product formed by injection molding is removed from the mold, is coated with paint by, for example, spraying or 25 dipping, and is dried to form a hard coating covering the

surface of the molded product for decoration and protection.

The term "coating material" may hereinafter be used as a synonym of "paint".

In recent years, however, in-mold coating (which may be referred to as in-mold coating) has been proposed, in which resin is molded and coated in the same mold to eliminate the step of painting.

Fig. 12 shows a flow chart of an example of a known in-mold coating method. According to the in-mold coating method in Fig. 12, a thermoplastic resin, namely a base material, is molded by injection molding and is cooled to some extent. The mold is then slightly opened to form a gap between the resin molded product formed in the mold and the mold cavity. Paint is injected into the gap with a paint-injector. The mold is clamped again to uniformly spread the paint over the surface of the molded product. The spread paint is cured to form a coating.

Because the thermoplastic resin is molded and coated in the same mold, the in-mold coating method involves fewer steps to achieve cost reduction. In addition, this method poses almost no problems such as defects caused by airborne dust adhering to a wet coating to provide high-quality products.

Studies have been made on the use of the in-mold coating method particularly for many automobile parts, such

as bumpers, doors, door mirror covers, and fenders, which need high quality in external appearance.

Examples of the in-mold coating method are disclosed in, for example, Japanese Unexamined Patent Application 5 Publication Nos. 11-277577 (Patent Document 1), 2000-141407 (Patent Document 2), 2000-334800 (Patent Document 3), and 2001-38737 (Patent Document 4).

According to the above known in-mold coating methods, however, mold-clamping force cannot be exerted on paint, 10 namely a coating material, in reclamping if the amount of paint injected is small. Unfortunately, therefore, these methods cannot form a uniform coating on the overall coating surface of a resin molded product.

One of the causes of the nonuniform coating thickness 15 is the decrease in the volume of the molded resin due to thermal contraction in the mold. When the thickness of the molded product decreases by thermal contraction, a gap occurs between the resin molded product and the cavity surface in the cavity. The gap is difficult to fill with 20 paint in an amount equivalent to the desired thickness. As a result, the paint cannot be spread over the surface to be coated, and a uniform coating cannot be formed.

To solve the above problem, the amount of coating material injected may be increased to solve the problem of 25 defective transfer of the mold surface to the coating

material, though this approach poses another problem of a larger coating thickness than necessary.

Another cause of the nonuniform coating thickness is mold deformation in molding. A typical mold has high 5 rigidity, but deforms by several to tens of micrometers when clamped with a clamping machine. Such degrees of deformation are often negligible in general resin molding. In in-mold coating, however, a resin molded product is generally coated with a coating having a thickness of about 10 tens of micrometers. Thus the deformation of the mold cavity due to mold deformation is listed as one of the causes of a nonuniform coating thickness.

According to a known in-mold coating method, particularly, mold-clamping force after paint injecting may 15 be changed stepwise. This method, however, results in a nonuniform coating thickness because the degree of mold deformation varies depending on the magnitude of the mold-clamping force to cause variations in the distance between the surface of a resin molded product and the mold cavity.

20 Referring to Figs. 10(a) to 10(d), a gap may be formed between a resin molded product formed under general injection molding conditions and a mold cavity surface by thermal contraction of molten resin charged into the mold cavity even if the mold is not opened. Because the size of 25 the gap varies depending on, for example, the shape of the

mold cavity and the thickness of the resin molded product, a uniform gap rarely occurs over the surface to be coated. In in-mold coating, therefore, the mold must be opened to ensure a necessary coating thickness. If, however, the 5 mold is opened, the resultant coating is undesirably extremely thick at a portion where the gap formed by thermal contraction combines with that formed by opening the mold.

If molten resin with a volume exceeding the capacity of 10 the mold cavity is charged into the mold cavity by applying excessive charging pressure to compensate for the volume of thermal contraction of the resin, the excessive charging pressure undesirably causes, for example, variations in the thickness of a resin molded product, as shown in Figs. 15 11(a) to 11(d). In an embodiment of the related art, in Figs. 11(a) to 11(d), the excessive injection pressure causes a difference in thickness between the ends of the resin molded product and the portion around a gate part.

In addition, excessive reclamping pressure after paint 20 injecting is undesirable because the pressure causes a phenomenon called a hump at a thick portion such as a rib and a boss. To prevent the defect, mold-clamping force after the injecting of coating material must be reduced, though a large difference between mold-clamping force in 25 resin injection and that after the injecting of coating

material undesirably results in a nonuniform coating thickness.

#### Disclosure of Invention

5        In light of the above problems, the present invention provides an in-mold coating method suitable for providing a uniform coating thickness to produce a molded product with an excellent external appearance, and also provides an in-mold-coated molded product formed by the in-mold coating  
10      method.

      To achieve the above object, the present invention provides an in-mold coating method in which a resin molded product is molded and coated in a mold cavity formed between female and male molds. This method includes a  
15      first step of charging molten resin into the mold cavity, a second step of molding the resin molded product after the charge of the molten resin into the mold cavity by reducing the volume of the mold cavity in accordance with the thermal contraction of the molten resin to shape the molten  
20      resin, a third step of forming a gap for injecting a coating material between the resin molded product and the surface of the mold cavity by slightly opening the mold when the resin molded product solidifies to the extent to which the product can withstand the injecting pressure and  
25      flowing pressure of the coating material, and a fourth step

of injecting the coating material into the gap and clamping the mold again. The mold-clamping forces in the second and fourth steps are controlled so that the deformation of the mold by clamping is substantially the same in the second  
5 and fourth steps.

This aspect is referred to as a first aspect of the present invention. In this aspect, the mold-clamping forces used in the second and fourth steps are preferably substantially the same. Substantially the same mold-  
10 clamping force means that the difference between the mold-clamping forces in terms of in-mold pressures obtained by dividing the forces by the projected area of the mold cavity is 5 MPa or less, preferably 3 MPa or less, more preferably 1 MPa or less. In addition, the pressure of the  
15 mold-clamping force in the fourth step on the coating material per unit area preferably ranges from 1 to 20 MPa, more preferably from 1 to 10 MPa. Furthermore, the mold-clamping force used in the second step is preferably smaller than that used in the first step, more preferably  
20 10% to 50% of that used in the first step, still more preferably 10% to 25% of that used in the first step.

The present invention further provides another in-mold coating method in which a resin molded product is molded and coated in a mold cavity formed between female and male  
25 molds. This method includes a first step of charging

molten resin into the mold cavity, a second step of molding the resin molded product after the charge of the molten resin into the mold cavity by reducing the volume of the mold cavity in accordance with the thermal contraction of 5 the molten resin to shape the molten resin, a third step of forming a gap for injecting a coating material between the resin molded product and the surface of the mold cavity by slightly opening the mold when the resin molded product solidifies to the extent to which the product can withstand 10 the injecting pressure and flowing pressure of the coating material, and a fourth step of injecting the coating material into the gap and clamping the mold again. The mold-clamping force used in the second step is smaller than that used in the first step.

15 This aspect is referred to as a second aspect of the present invention. In this aspect, the mold-clamping force used in the second step is preferably 10% to 50%, more preferably 10% to 25%, of that used in the first step. The mold-clamping force used in the second step preferably 20 ranges from 2 to 15 MPa, more preferably from 4.0 to 10 MPa, in terms of in-mold pressure per unit area.

The present invention further provides another in-mold coating method in which a resin molded product is molded and coated in a mold cavity formed between female and male 25 molds. This method includes a first step of charging

molten resin into the mold cavity, a second step of molding the resin molded product after the charge of the molten resin into the mold cavity by reducing the volume of the mold cavity in accordance with the thermal contraction of 5 the molten resin to shape the molten resin, and a third step of injecting a coating material between the resin molded product and the surface of the mold cavity when the resin molded product solidifies to the extent to which the product can withstand the injecting pressure and flowing 10 pressure of the coating material. The mold-clamping force used in the second step is substantially the same as that used in the third step.

This aspect is referred to as a third aspect of the present invention. In this aspect, the mold-clamping 15 forces used in the second and third steps are preferably substantially the same. The pressure of the mold-clamping force in the third step on the coating material per unit area preferably ranges from 1 to 20 MPa, more preferably from 1 to 10 MPa. In addition, the mold-clamping force 20 used in the second step is preferably smaller than that used in the first step, more preferably 10% to 50% of that used in the first step, still more preferably 10% to 25%.

The present invention further provides another in-mold coating method in which a resin molded product is molded 25 and coated in a mold cavity formed between female and male

molds. This method includes a first step of charging molten resin into the mold cavity, a second step of molding the resin molded product after the charge of the molten resin into the mold cavity by reducing the volume of the 5 mold cavity in accordance with the thermal contraction of the molten resin to shape the molten resin, and a third step of injecting a coating material between the resin molded product and the surface of the mold cavity when the resin molded product solidifies to the extent to which the 10 product can withstand the injecting pressure and flowing pressure of the coating material. The mold-clamping force used in the second step is smaller than that used in the first step.

This aspect is referred to as a fourth aspect of the 15 present invention. In this aspect, the mold-clamping force used in the second step preferably is 10% to 50%, preferably 10% to 25%, of that used in the first step. The mold-clamping force used in the second step preferably ranges from 2 to 15 MPa, more preferably from 4.0 to 10 MPa, 20 in terms of in-mold pressure per unit area.

The present invention further provides an in-mold-coated molded product formed according to any one of the first to fourth aspects described above.

In the present invention, substantially the same mold- 25 clamping force means that the difference in mold-clamping

force in terms of in-mold pressure obtained by dividing mold-clamping force by the projected area of a mold cavity is 5 MPa or less, preferably 3 MPa or less, more preferably 1 MPa or less.

5       In the first to fourth aspects of the present invention, the first step includes moving a moving mold to a position at which the mold forms a cavity with a predetermined volume, injecting the molten resin into the cavity with an injection machine, and further moving the moving mold to a 10 desired position after the completion of the injection.

In the first and second aspects of the present invention, the second step includes molding the resin molded product after the charge of the molten resin into the mold cavity by reducing the volume of the mold cavity 15 in accordance with the thermal contraction of the injected molten resin by cooling to shape the injected and solidified resin.

In the first and second aspects of the present invention, the third step, on the completion of the second 20 step, includes forming a gap between the resin molded product and the surface of the mold cavity by moving the moving mold to slightly open the mold when the resin molded product solidifies to the extent to which the product can withstand the injecting pressure and flowing pressure of 25 the coating material.

In the third and fourth aspects of the present invention, the third step, on the completion of the second step, includes solidifying the resin molded product to the extent to which the product can withstand the injecting pressure and flowing pressure of the coating material, and then injecting the coating material between the resin molded product and the surface of the mold cavity while keeping the state.

In the first and second aspects of the present invention, the fourth step includes injecting the coating material into the gap formed in the third step, clamping the mold again, and curing the coating material in that state.

15 Brief Description of the Drawings

Fig. 1 is a schematic diagram illustrating the structure of a mold for in-mold coating according to a first embodiment of the present invention.

Figs. 2(a) to 2(d) are schematic diagrams illustrating the behaviors of the mold, resin, and paint in an in-mold coating method according to the first embodiment of the present invention.

Fig. 3 is an overall schematic view showing the overall structure of an in-mold coating apparatus used in the present invention.

Fig. 4 is a schematic diagram illustrating the structure of a mold for in-mold coating according to a second embodiment of the present invention.

Figs. 5(a) to 5(d) are schematic diagrams illustrating 5 the behaviors of the mold, resin, and paint in an in-mold coating method according to the second embodiment of the present invention.

Fig. 6 is a flow chart of the in-mold coating methods according to the first and second embodiments of the 10 present invention.

Fig. 7 is a projection view of resin molded products molded in Examples 1 to 3 of the present invention and Comparative Examples 1 to 3 in a mold opening/closing direction, showing measurement points of coating thickness.

Fig. 8 is a sectional view of resin molded products 15 molded in Example 8 of the present invention and Comparative Example 6, in which arrows indicate the measurement points of coating thickness.

Fig. 9 is a graph showing variations in coating 20 thickness ( $\mu\text{m}$ ) at the measurement points of the resin molded products molded in Example 8 of the present invention and Comparative Example 6.

Figs. 10(a) to 10(d) are schematic diagrams 25 illustrating the behaviors of a mold, resin, and paint in a know method.

Figs. 11(a) to 11(d) are schematic diagrams illustrating the behaviors of a mold, resin, and paint in another known method.

Fig. 12 is a flow chart of a known in-mold coating  
5 method.

Reference numerals used in the attached drawings indicate the following machines, components, parts, etc.:

10 and 10A: Mold for in-mold coating

12 and 12A: Fixed mold

10 14 and 14A: Moving mold

15 and 15A: Mold cavity

20: Mold-clamping machine

30: Injection machine

50: Paint-injector

15 51: Paint inlet

60: Control device

100: Injection apparatus

#### Best Mode for Carrying Out the Invention

20 In-mold coating methods according to preferred embodiments of the present invention will now be described with reference to the drawings.

Figs. 1 to 3 relate to a first embodiment of the present invention. Fig. 1 is a schematic diagram  
25 illustrating the structure of a mold for in-mold coating

according to this embodiment. Figs. 2(a) to 2(d) are schematic diagrams illustrating the behaviors of the mold, resin, and paint in an in-mold coating method according to this embodiment. Fig. 3 is an overall schematic view 5 showing the overall structure of an in-mold coating apparatus used in this embodiment.

Figs. 4 and 5(a) to 5(d) relate to a second embodiment of the present invention. Fig. 4 is a schematic diagram illustrating the structure of a mold for in-mold coating 10 according to a second embodiment of the present invention. Figs. 5(a) to 5(d) are schematic diagrams illustrating the behaviors of the mold, resin, and paint in an in-mold coating method according to the second embodiment. Fig. 6 is a flow chart of the in-mold coating methods according to 15 the first and second embodiments of the present invention. Fig. 7 is a projection view of resin molded products molded in Examples 1 to 3 of the present invention and Comparative Examples 1 to 3 in a mold opening/closing direction, showing measurement points of coating thickness. Fig. 8 is 20 a sectional view of resin molded products molded in Example 8 of the present invention and Comparative Example 6, in which arrows indicate the measurement points of coating thickness. Fig. 9 is a graph showing variations in coating thickness ( $\mu\text{m}$ ) at the measurement points of the resin molded 25 products molded in Example 8 of the present invention and

Comparative Example 6. Figs. 10(a) to 10(d) and 11(a) to 11(d) are schematic diagrams illustrating the behaviors of a mold, resin, and paint in known methods. Fig. 12 is a flow chart of a known in-mold coating method.

5 The structure of a preferred example of an in-mold coating mold 10A (which may also be referred to as a mold 10A) according to the first embodiment of the present invention is briefly described below with reference to Fig. 1.

10 The mold 10A according to the present invention has a moving mold 14A, a fixed mold 12A, and a paint-injector 50. In the embodiment shown in Fig. 1, the moving mold 14A is a female mold, and the fixed mold 12A is a male mold. A mold cavity 15A is flat, as shown in the sectional view of Fig.

15 1.

Next, the paint-injector 50 is briefly described below. In this embodiment, the paint-injector 50 is attached to the moving mold 14A so as to inject paint into the mold cavity 15A through a paint inlet 51 provided at the mold cavity surface of the moving mold 14A. A valve (not illustrated) is attached to the paint inlet 51 of the paint-injector 50. In injection molding, this valve is closed to prevent resin injected into the mold cavity 15A of the mold 10A from entering the paint-injector 50 through the paint inlet 51.

The paint-injector 50 according to this embodiment is driven by a drive unit (not illustrated) to accurately inject a desired amount of paint fed into the paint-injector 50 from the mold cavity surface of the moving mold 14A.

5 14A.

Though, as described above, the paint-injector 50 in this embodiment injects paint from the mold cavity surface of the moving mold 14A, the present invention is not limited to the above structure. The paint-injector 50 may 10 be, for example, attached to the fixed mold 12A as long as the paint can be injected into a gap between a resin molded product formed in the mold cavity 15A and the mold cavity surface.

A preferred example of an in-mold coating method 15 according to this embodiment will now be described with reference to Figs. 1 to 3 and 6.

As a first step, the mold 10A is opened by a mold-clamping machine 20 to form the mold cavity 15A. This mold cavity 15A has a larger volume than a resin molded product 20 described later by the volume of thermal contraction of molten resin.

The mold 10A requires such a structure that the volume of the mold cavity 15A can be reduced by the volume of thermal contraction of molten resin in the subsequent step. 25 The fixed mold 12A and the moving mold 14A must be arranged

so that the volume of the mold cavity 15A can be reduced by the volume of thermal contraction after the injection of molten resin using, for example, the above mold shown in Fig. 1, which has a fit portion with a pinch-off structure.

5        After the mold cavity 15A, which has a larger volume than the desired resin molded product by the volume of thermal contraction of molten resin, is formed, a molten thermoplastic resin is injected as a base material into the mold cavity 15A with an injection machine 30 (not illustrated), as shown in Fig. 2(a) (the base material used in this embodiment is a heat-resistant ABS resin, namely UT20B, manufactured by UMG ABS, Ltd.). In this embodiment, when the molten resin is charged, the hydraulic pressure of a mold-clamping cylinder 22 (not illustrated) provided to a 15 toggle clamping mechanism 23 (not illustrated) is controlled so that the position of a moving platen 28 (not illustrated) is kept unchanged during the injection to minimize variations in the volume of the mold cavity 15A.

20       The maximum mold-clamping force  $P_{max}$  required for keeping the position of the moving platen 28 substantially unchanged is divided by the projected area  $S$  of the resin molded product in a mold opening/closing direction to determine a surface pressure  $M_{max}$  per unit area, as represented by the following formula 1:

$$M_{max} = P_{max}/S$$

The surface pressure  $M_{max}$  is determined to be 50 MPa (megapascals). In general, the surface pressure  $M_{max}$  is at 5 least 30 MPa or more except for some injection compression methods or injection pressing methods called low-pressure molding, though the value depends on many factors such as the shape and size of the molded product, the type of resin, and melting temperature.

10 In this embodiment, the position of the moving platen 28 is controlled so as to minimize variations in the volume of the mold cavity 15A. However, the mold-clamping manner in the first step which is applicable to the present invention the first step is not limited to the above- 15 mentioned mold-clamping manner. One may control the mold-clamping machine so as to increase the volume of the mold cavity 15A by opening the mold 10A with the charging pressure of the molten resin during the charge of the molten resin, alternatively.

20 In a second step after the completion of the injection of the molten resin into the mold cavity 15A, the molten resin is cooled and solidified to the extent to which the resin can withstand the injecting pressure of a coating material described later. Immediately after the completion 25 of the injection of the molten resin, the volume of the

mold cavity 15A is at least larger than that of the resin molded product described later by the volume of thermal contraction of the molten resin. In this embodiment, the mold-clamping force in the second step is changed to 1,000 5 kN (kilo-newtons) from the one used in the first step. Thus, the surface pressure per unit area becomes 5 MPa, which is obtained by dividing the mold-clamping force by the projected area S of the resin molded product (2,000 cm<sup>2</sup> in the first embodiment).

10 When clamped in this state, the mold 10A is closed gradually in accordance with the thermal contraction of the molten resin in the mold cavity 15A, and the molten resin is shaped.

15 Referring to Fig. 2(c), in a third step after the cooling of the base material, the mold is slightly opened (the moving mold 14A is moved in the mold-opening direction by about 1 mm in the first embodiment) to form a gap between the resin molded product formed in the mold cavity 15A and the mold cavity surface of the moving mold 14A.

20 After the gap is formed, 20 mL of paint is injected into the mold cavity 15A through the paint inlet 51 by the paint-injector 50. The paint then starts to flow into the gap formed by opening the mold 10A. The area of the coating surface of the molded product formed with the mold 25 used in this embodiment is 2,000 cm<sup>2</sup>, and the coating

thickness is about 0.1 mm. The paint used in the first embodiment is Plaglass #8,000 white (manufactured by Dai Nippon Toryo Co., Ltd.).

Referring to Fig. 2(d), in a fourth step after the 5 paint injecting, the mold 10A is closed and clamped again by moving the moving mold 14A toward the fixed mold 12A to allow the paint to spread and flow in the gap, thus coating the molded product with the paint.

In the first embodiment, the mold-clamping force in the 10 fourth step is 1,000 kN, and the surface pressure (which may also be referred to as in-mold pressure per unit area) obtained by dividing the mold-clamping force by the projected area S of the resin molded product is 5 MPa.

Advantages of the in-mold coating method according to 15 the first embodiment are described below. In the first embodiment, the volume of the mold cavity 15A is reduced in accordance with the thermal contraction of the molten resin in the second step, so that most of the coating surface of the resin molded product is kept pressed against the mold 20 cavity surface until immediately before coating. By molding the resin molded product in this state, the surface profile of the mold cavity can be precisely transferred to the surface of the resin molded product. This method can therefore prevent the conventional problem of a nonuniform 25 coating thickness effectively.

In this embodiment, additionally, the mold-clamping force in the second step, in which the shape of the resin molded product is fixed, and that in the fourth step are selected so that the forces are substantially the same.

5 As described in the section of Background Art, a nonuniform coating thickness is caused by mold deformation in molding.

Substantially the same mold-clamping force may be used in the second and fourth steps so that the mode and degree 10 of deformation of the mold cavity 15 in the second step are close to those of the mold cavity 15 in the fourth step.

This method has the excellent effect, even if the mold cavity 15 deforms to some degree by the mold-clamping force in the second step, since the mold cavity 15 also deforms 15 similarly in the fourth step to provide a uniform coating thickness.

Accordingly, the above effect is produced and enhanced as the mold-clamping forces in the second and fourth steps approach each other. The mold-clamping forces in the 20 second and fourth steps are therefore preferably substantially the same, namely 5 MPa or less in terms of the difference in surface pressure (the pressure per unit area obtained by dividing mold-clamping force by the projected area S of the resin molded product) between the 25 second and fourth steps, more preferably 3 MPa or less,

most preferably 1 MPa or less.

In addition, the pressure of the mold-clamping force in the fourth step on the coating material per unit area preferably ranges from 1 to 20 MPa, more preferably from 1 5 to 10 MPa. Excessive reclamping force after the paint injecting undesirably causes, for example, a phenomenon called a hump at a thick portion such as a rib and a boss.

Next, a second embodiment of the present invention will now be described. The following description focuses on 10 parts different from the embodiment described above.

The structure of an in-mold coating mold 10 (which may also be referred to as a mold 10) according to the second embodiment of the present invention is briefly described below with reference to Fig. 4.

15 As in the case of the mold 10A used in the first embodiment described above, the mold 10 according to the present invention has a moving mold 14, a fixed mold 12, and a paint-injector 50. The fixed mold 12 and the moving mold 14 are fitted at a fit portion with a pitch-off 20 structure. A pitch-off portion is formed all around a mold cavity 15. The mold cavity 15 of the mold 10 is box-shaped, having a sidewall portion extending in a mold closing direction on the periphery of the mold cavity 15 and an opening, as shown in the sectional view of Fig. 4. The 25 fixed mold 12, which is a male mold, and the moving mold 14,

which is a female mold, are fitted at the fit portion with the pitch-off structure to form the mold cavity 15A inside the mold 10. The fit portion with the pitch-off structure (which may also be referred to as a pitch-off portion) is 5 formed all around the mold cavity 15.

The pinch-off portion of the mold 10 can prevent the resin charged into the mold cavity 15 from leaking from the mold 10.

The arrangement and structure of the paint-injector 50 10 are not described since they are the same as in the embodiment described above.

An in-mold coating method according to the second embodiment of the present invention will now be described with reference to Figs. 5(a) to 5(d). In the in-mold 15 coating method according to the second embodiment, as a first step, the mold 10 is opened by a mold-clamping machine 20 to form the mold cavity 15. As in the first embodiment described above, the mold cavity 15 has a larger volume than a resin molded product by the volume of thermal 20 contraction of molten resin. Subsequently, as is done in the first embodiment, a heat-resistant ABS resin is injected into the mold cavity 15, and the operation proceeds to the second step wherein the mold 10 is gradually closed in accordance with the thermal contraction 25 of the molten resin in the mold cavity 15.

In this embodiment, the mold-clamping force in the second step is significantly reduced compared with that in the first step to make smaller the surface pressure per unit area obtained by dividing the mold-clamping force by 5 the projected area  $S$  of the resin molded product. That is, the mold-clamping force in the second step is preferably 10% to 50%, more preferably 10% to 25%, of that in the first step. In this embodiment, the surface pressure  $M_2$  in the second step is 5 MPa, which is equivalent to 10% of the 10 surface pressure  $M_1$  in the first step.

Referring to Fig. 5(c), in a third step after the cooling of the base material, the mold is slightly opened (the moving mold 14 is moved in the mold-opening direction by about 1 mm in this embodiment) to form a gap between the 15 resin molded product formed in the mold cavity 15 and the mold cavity surface of the moving mold 14.

After the gap is formed, 25 mL (milliliters) of coating material is injected into the mold cavity 15 through the paint inlet 51 by the paint-injector 50. The coating 20 material then starts to flow into the gap formed by opening the mold 10 and a gap formed at the sidewall portion.

The area of the coating surface of the molded product formed with the mold used in this embodiment is 2,500 cm<sup>2</sup>, and the coating thickness is about 0.1 mm. The coating 25 material used in this embodiment is Plaglass #8,000 white

(manufactured by Dai Nippon Toryo Co., Ltd.).

Referring to Fig. 5(c), in a fourth step after the injecting of the coating material (paint), the mold 10 is closed and clamped again by moving the moving mold 14 5 toward the fixed mold 12 to allow the coating material to spread and flow in the gap, thus coating the molded product with the coating material.

In this embodiment, a surface pressure  $M_3$  per unit area obtained by dividing the mold-clamping force in the fourth 10 step by the projected area  $S$  of the resin molded product is selected so that the deformation of the mold cavity is substantially the same in the second and fourth steps, preferably so that the surface pressures in the second and fourth steps are substantially the same. In this 15 embodiment, the surface pressure  $M_3$  used in the fourth step is 5 MPa, which is the same as that in the second step.

Advantages of the in-mold coating method according to this embodiment are described below. In this embodiment, the volume of the mold cavity 15 is reduced in accordance 20 with the thermal contraction of the molten resin in the second step, so that the resin molded product is kept pressed against the mold cavity surface until immediately before coating.

By molding the resin molded product in this state, the 25 surface profile of the mold cavity can be precisely

transferred to the surface of the resin molded product. The resultant product has a clear surface and almost no thin part due to, for example, thermal contraction. This method can therefore prevent the conventional problem of a 5 nonuniform coating thickness resulting from a decrease in the thickness of the resin molded product by thermal contraction effectively.

In this embodiment, additionally, the mold-clamping force in the second step, in which the shape of the resin 10 molded product is fixed, is significantly reduced compared with that in the first step. As is discussed in the description of the problems to be solved, another cause of a nonuniform coating thickness is mold deformation in molding. The degree of deformation of the mold 10 is 15 usually designed according to the mold-clamping force  $P_{max}$  in the first step. If, therefore, the mold-clamping force in the second step is smaller than that in the first step, the effect of suppressing the deformation of the mold 10 can be achieved to provide a uniform coating thickness.

20 A preferred range of mold-clamping force in the second step, namely the range effective in practical molding, is 50% or less of the mold-clamping force in the first step.

In addition, the reduction of the mold-clamping force in the second step allows a slight gap to occur gradually 25 by thermal contraction at the sidewall portion of the resin

molded product. As a result, the coating material can flow to the sidewall portion to form an excellent coating.

As described above, the mold-clamping force  $P_{max}$  in the first step is designed according to the surface pressure, 5 namely the pressure on the resin molded product per unit area. The mold-clamping force  $P_{max}$  in the first step is usually adjusted to 30 MPa or more in terms of surface pressure. Accordingly, the pressure of the mold-clamping force in the second step on the resin molded product per 10 unit area is preferably 15 MPa or less, and is more preferably 10 MPa or less in view of enhancing the effects. In addition, the surface pressure is also required for keeping the resin molded product pressed against the mold cavity surface until immediately before coating. The mold- 15 clamping force in the second step therefore preferably ranges from 2 to 15 MPa, more preferably from 4 to 10 MPa, in terms of in-mold pressure per unit area.

In addition, the pressure of the mold-clamping force in the fourth step on the coating material per unit area 20 preferably ranges from 1 to 20 MPa, more preferably from 1 to 10 MPa. Excessive reclamping force after the paint injecting undesirably causes, for example, a phenomenon called a hump at a thick portion such as a rib and a boss.

An in-mold coating method according to a third 25 embodiment will now be described with reference to Fig.

2(a) to 2(d) for reference.

Referring to Fig. 2(a), as a first step, the mold 10A is opened by the mold-clamping machine 20 (not illustrated) to form the mold cavity 15A. As in the embodiments 5 described above, this mold cavity 15A has a larger volume than a resin molded product by the volume of thermal contraction of molten resin.

After the mold cavity, which has a larger volume than the resin molded product by the volume of thermal 10 contraction of the molten resin, is formed, a molten thermoplastic resin is injected as a base material into the mold cavity 15A with the injection machine 30 (not illustrated in Fig. 2) (the base material used in the third embodiment is a heat-resistant ABS resin, namely UT20B, 15 manufactured by UMG ABS, Ltd.).

The mold-clamping force used in the resin injection is 3,000 kN.

Referring to Fig. 2(b), in a second step after the completion of the injection of the molten resin into the 20 mold cavity 15A, the molten resin is cooled and solidified to the extent to which it can withstand the injecting pressure of the coating material described later. Here, the volume of the mold cavity 15A immediately after the completion of the injection of the molten resin is larger 25 than that of the resin molded product described later at

least by the volume of thermal contraction of the molten resin.

In the third embodiment, additionally, the mold-clamping force in the second step is changed to 1,000 kN from the one in the first step. The surface pressure per unit area is 5 MPa, which is obtained by dividing the mold-clamping force by the projected area S of the resin molded product (2,000 cm<sup>2</sup> in the third embodiment). When clamped in this state, the mold 10A closes gradually in accordance with the thermal contraction of the molten resin in the mold cavity 15A to shape the molten resin.

In a third step after the cooling of the base material, 20 mL of paint is injected into the mold cavity 15A through the paint inlet 51 by the paint-injector 50.

The paint is injected with higher pressure to slightly open the mold 10A by the paint-injecting pressure so that the paint can flow into the mold cavity 15A to coat the molded product with the paint. The area of the coating surface of the molded product formed with the mold used in the third embodiment is 2,000 cm<sup>2</sup>, and the coating thickness is about 0.1 mm. The paint used in this embodiment is Plaglass #8,000 white (manufactured by Dai Nippon Toryo Co., Ltd.). In the third embodiment, the mold-clamping force in the third step is 1,000 kN, and the surface pressure per unit area is 5 MPa, which is obtained by dividing the mold-

clamping force by the projected area  $S$  of the resin molded product.

An in-mold coating method according to a fourth embodiment will now be described with reference to Fig. 5 2(a) to 2(d) for reference.

Referring to Fig. 2(a), as a first step, the mold 10A is opened by the mold-clamping machine 20 (not illustrated) to form the mold cavity 15A. As in the embodiments described above, this mold cavity 15A has a larger volume 10 than a resin molded product by the volume of thermal contraction of molten resin.

After the mold cavity 15A, which has a larger volume than the resin molded product by the volume of thermal contraction of the molten resin, is formed, a molten 15 thermoplastic resin is injected as a base material into the mold cavity 15A with the injection machine 30 (not illustrated) (the base material used in the fourth embodiment is a heat-resistant ABS resin, namely UT20B, manufactured by UMG ABS, Ltd.).

20 The mold-clamping force used in the resin injection is 3,000 kN.

Referring to Fig. 2(b), in a second step after the completion of the injection of the molten resin into the mold cavity 15A, the molten resin is cooled and solidified 25 to the extent to which it can withstand the injecting

pressure of the coating material described later. Here, the volume of the mold cavity 15A immediately after the completion of the injection of the molten resin is larger than that of the resin molded product described later at 5 least by the volume of thermal contraction of the molten resin.

In the fourth embodiment, additionally, the mold-clamping force in the second step is changed to 1,000 kN from the one in the first step. The surface pressure per 10 unit area is 5 MPa, which is obtained by dividing the mold-clamping force by the projected area S of the resin molded product (2,000 cm<sup>2</sup> in the fourth embodiment). When clamped in this state, the mold 10A closes gradually in accordance with the thermal contraction of the molten resin in the 15 mold cavity 15A to shape the molten resin. For the same reason as in the embodiments described above, the mold-clamping force in the second step is preferably 15 MPa or less in terms of in-mold pressure per unit area, and is more preferably 10 MPa or less in view of enhancing the 20 effects. In addition, preferably, the mold-clamping force in the second step ranges from 2 to 15 MPa in terms of in-mold pressure per unit area.

In a third step after the cooling of the base material, 20 mL of paint is injected into the mold cavity 15A through 25 the paint inlet 51 by the paint-injector 50.

The paint is injected with higher pressure to slightly open the mold 10A by the paint-injecting pressure so that the paint can flow into the mold cavity 15A to coat the molded product with the paint. The area of the coating 5 surface of the molded product formed with the mold used in the fourth embodiment is 2,000 cm<sup>2</sup>, and the coating thickness is about 0.1 mm. The paint used in this embodiment is Plaglass #8,000 white (manufactured by Dai Nippon Toryo Co., Ltd.). In the fourth embodiment, the 10 mold-clamping force in the third step is 2,000 kN, and the surface pressure per unit area is 10 MPa, which is obtained by dividing the mold-clamping force by the projected area S of the resin molded product.

According to the third and fourth embodiments, the same 15 effects as in the first and second embodiments can be achieved for the same reasons as in the first and second embodiments.

As described above, the present invention may be applied not only to methods in which paint is injected into 20 a mold opened in advance, but also to methods in which a mold is opened by paint-injecting pressure, as shown in the third and fourth embodiments. The same effects as in the first and second embodiments can be achieved for the same reasons as in the first and second embodiments.

25 The present invention will be further described below

with examples, though they do not limit the scope of the present invention.

(Examples 1 to 3 and Comparative Examples 1 to 3)

A heat-resistant ABS resin (UT20B, manufactured by UMG 5 ABS, Ltd.) was molded in a mold having a projected shape shown in Fig. 7 and a projected area of about 2,400 cm<sup>2</sup> with varying mold-clamping forces in the second step. Table 1 shows the measurement results of the thickness of the molded products. In Fig. 7, circled numbers indicate 10 measurement points.

(Table 1)

## Molded product thickness

Examples/ Comparative examples	Comparative Example 1	Comparative Example 2	Example 1	Example 2	Example 3	Comparative Example 3
Mold-clamping force in first step (ton)	850	850	850	850	850	850
Mold-clamping force in second step (ton)	850	400	300	200	100	50
Maximum thickness (mm)	3.262	3.186	3.257	3.240	3.243	-
Minimum thickness (mm)	3.050	2.988	3.141	3.154	3.164	-
Difference between maximum and minimum thicknesses	0.212	0.198	0.116	0.086	0.079	-
Average	3.15	3.11	8.20	3.21	3.21	-
Standard deviation	0.058	0.058	0.038	0.035	0.029	-
Surface condition	Good	Good	Good	Good	Good	Sink marks occurred

The molded products of Comparative Examples 1 and 2, in which the mold-clamping force in the second step exceeded 50% of that (850 tons) in the first step, had large variations in thickness. On the other hand, the molded products of Examples 1 to 3, in which the mold-clamping force in the second step was within the range of 10% to 50% of that in the first step, had smaller variations in thickness. In Comparative Example 3, in which the mold-clamping force in the second step was below 10% of that in the first step, sink marks occurred obviously on the surface of the molded product.

(Examples 4 to 7 and Comparative Examples 4 to 5)

In-mold coating was performed in the same mold using a heat-resistant ABS resin (UT20B, manufactured by UMG ABS, Ltd.) and paint (Plaglass #8,000 red, manufactured by Dai Nippon Toryo Co., Ltd.) with varying mold-clamping forces in the second and fourth steps. Table 2 shows the measurement results of the thickness of the molded products.

(Table 2)

Molding conditions and coating thickness

Examples/ comparative examples	Example 4	Comparative Example 4	Comparative Example 5	Comparative Example 5	Example 6	Example 7
Mold-clamping force in first step (ton)	850	850	850	850	850	850
Mold-clamping force in second step (ton)	850	850	100	100	200	100
In-mold pressure in second step (MPa)	36	32	4	4	8	4
Mold-clamping force in fourth step (ton)	850	100	850	100	200	300
In-mold pressure in fourth step (MPa)	36	4	36	4	8	13
Maximum coating thickness (μm)	55	100	100	60	50	70
Minimum coating thickness (μm)	35	40	35	30	35	25
Difference (μm)	20	60	65	20	15	45

In Comparative Examples 4 and 5, the difference in mold-clamping force between the second and fourth steps was 750 tons, which is equivalent to about 30 MPa in terms of in-mold pressure. The difference between the maximum and 5 minimum coating thicknesses was 60  $\mu\text{m}$  or more, indicating that the coating thickness had large variations. In Examples 4 to 6, on the other hand, the mold-clamping forces in the second and fourth steps were controlled so that the forces were substantially the same. The 10 difference in coating thickness ranged from 15 to 20  $\mu\text{m}$ , indicating that a nearly uniform coating was formed. In Example 7, the difference in in-mold pressure was 8 MPa, which was an intermediate value between the examples and the comparative examples.

15 (Example 8 and Comparative Example 6)

In-mold coating was performed in a mold with the shape of a side cover (projected area: about 500  $\text{cm}^2$ ) using a heat-resistant ABS resin (UT20B, manufactured by UMG ABS, Ltd.) and paint (Plaglass #8,000 red, manufactured by Dai 20 Nippon Toryo Co., Ltd.) with varying mold-clamping forces in the second and fourth steps, as shown in Table 3 below. Fig. 8 shows measurement points at which the coating thickness of the resultant molded products was measured. The measurement points are indicated by the arrows above 25 the cross section. Fig. 9 shows the variations in coating

thickness at the measurement points.

(Table 3)

Example/Comparative example	Comparative Example 6	Example 8
Mold-clamping force in first step (ton)	200	200
Mold-clamping force in second step (ton)	200	50
In-mold pressure in second step (MPa)	41	10
Mold-clamping force in fourth step (ton)	50	50
In-mold pressure in fourth step (MPa)	10	10
Difference in in-mold pressure	31	0

5 In Example 8, the mold-clamping force in the second step was smaller than that in the first step. The results in Fig. 9 show that the coating thickness on the elevation surfaces at the ends of the resin molded product is close to that on the flat part of the resin molded product. In

10 10 Comparative Example 6, in which the mold-clamping force in the second step was the same as that in the first step, the coating was significantly thinner on the elevation surfaces at the ends of the resin molded product than on the flat part of the resin molded product.

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#### Industrial Applicability

In the present invention, the volume of the mold cavity

is reduced in accordance with the thermal contraction of the molten resin in the second step, so that the resin molded product is kept pressed against the mold cavity surface until immediately before coating. This allows an 5 excellent transfer of the mold cavity surface to provide a uniform coating on the overall coating surface of the resin molded product.

In the second step, in which the shape of the resin molded product is fixed, the mold-clamping force is 10 significantly reduced in comparison with the first step, namely 50% or less of the mold-clamping force in the first step. This produces the excellent effect of suppressing mold deformation to provide a uniform thickness for the overall coating. In addition, the mold-clamping force in 15 the second step, in which the shape of the resin molded product is fixed, and that in the fourth step are adjusted so that the cavity deformation is substantially the same in these steps. In other words, the same mold-clamping force is used in the second and fourth steps so that the mode and 20 degree of deformation of the mold cavity 15 in the second step are close to those of the mold cavity 15 in the fourth step. This produces the excellent effect that, even if the mold cavity deforms to some degree by mold-clamping force in the second step, the mold cavity also deforms similarly 25 in the fourth step to provide a uniform coating thickness.

In addition, the reduction of the mold-clamping force in the second step allows a slight gap to occur gradually by thermal contraction at the sidewall portion of the resin molded product. As a result, the coating material can flow 5 to the sidewall portion to form an excellent coating. The mold-clamping force in the second step described above is also required for keeping the resin molded product pressed against the mold cavity surface until immediately before coating. The mold-clamping force in the second step 10 therefore preferably ranges from 2 to 15 MPa, more preferably from 4 to 10 MPa, in terms of in-mold pressure per unit area.

The pressure of the mold-clamping force in the fourth step on the coating material per unit area preferably 15 ranges from 1 to 20 MPa, more preferably from 1 to 10 MPa. Excessive reclamping force after paint injecting undesirably causes, for example, a phenomenon called a hump at a thick portion such as a rib and a boss.

Furthermore, the present invention may be applied not 20 only to methods in which paint is injected into a mold opened in advance, but also to in-mold coating methods in which a mold is opened by paint-injecting pressure to achieve the same effects.